AQUARIUS/SAC-D

AQUARIUS LEVEL-2 DATA PRODUCT

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Aquarius Level-2 Data Product

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DOCUMENT CHANGE LOG

Change Number	Change Date	Pages Affected	Changes/ Notes	General Comments
-	12 February 2013	All	Version 2.0	

1.0 Introduction

This document describes the specifications of the Aquarius LeveL-2 archive products, which are produced and distributed by the NASA Goddard Space Flight Center's Aquarius Data Processing System (ADPS). The products are implemented in the Hierarchical Data Format 5 (HDF5), and HDF terminology is used in this document.

These specifications are given in terms of the logical implementation of the products in HDF and are not a physical description of file contents. Therefore, HDF software must be used to create or read these products.

An Aquarius Level-2 product is generated from one Aquarius Level-1A data file. It contains physical measurements as computed from the Level-1A raw data, either at the instrument or the observed surface locations along with coordinates of viewed locations and navigation data. This product is stored as one physical HDF file.

Each product contains data from one orbit of Aquarius data. An orbit is defined as starting when the SAC-D spacecraft passes the South Pole. An orbit may be downlinked multiple times (either to the CONAE ground stations at Cordoba or other stations supported by CONAE). The best quality data are selected for each orbit during the Level 0 to 1A data processing and used to create the input Level 1A file.

2.0 Naming Convention

The form of a Level-2 file name is Qyyyydddhhmmss.L2_ttt_vvvv, where Q is for Aquarius, yyyydddhhmmss are the concatenated digits for the UTC year, day of the year, hours, minutes, and seconds of the first sample (block) in the product, ttt is the type of data in the product, and vvvv is the processing version. Examples of file names are:

Q2013007015300.L2_SCI_V2.0 for standard science data product version 2.0.

3.0 Global Attributes

For global attributes that have constant values specific to this product type, the value is given.

3.1 Mission and Documentation

Product Name (character): the name of the product file (without path).

Title (character): "Aquarius Level-2 Data".

Data Center (character): "NASA/GSFC Aquarius Data Processing Center".

institution (charactger): “NASA/GSFC OBPG”

Mission (character): "SAC-D Aquarius".

Mission Characteristics (character): "Nominal orbit: inclination = 98.0 (Sun-synchronous); node = 6 PM (ascending); eccentricity = <0.002; altitude = 657 km; ground speed = 6.825 km/sec".

Sensor (character): "Aquarius".

Sensor Characteristics (character): "Number of beams = 3; channels per receiver = 4; radiometer frequency = 1.413 GHz; scatterometer frequency = 1.26 GHz; bits per sample = 16; instantaneous radiometer field-of-view = 6.5 degrees; instantaneous scatterometer field-of-view = 4.9 degrees; science data block period = 1.44 sec.”

Data Type (character): “SCI”

3.2 Processing Information

Software ID (character): identifies version of the software used to create this product.

Processing Version (character): identifies the version of the products, e.g. V1.0.

Processing Time (character): local time of generation of this product; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

Conventions (character): “CF-1.6”; Climate and Forecast (CF) metadata conventions used.

_**lastModified** (character): same as **Processing Time**; added for CF compliance.

Input Files (character): the name of the Level-1A file (without path) from which the current product was created.

RAD_ANCILLARY_FILEn (character): the names of the ancillary data files (without path) used to process the radiometer data, where **n** = 1, 2, or 3. Depending on the timing of the Aquarius granule with respect to the ancillary data times, there may be either 2 or 3 sets of data with corresponding instances of this attribute.

Scatterometer Ancillary Files (character): the names of the ancillary files (without path) used to process the scatterometer data.

Radiometer Calibration Files (character): the names of the radiometer calibration coefficient files (without path) used to process the radiometer data.

Radiometer Data Tables (character): the names of the radiometer look-up table files (without path) used to process the radiometer data.

Scatterometer Coefficient Files (character): the names of the scatterometer coefficient files (without path) used to process the scatterometer data.

Processing Control (character): input and processing control parameters used to generate the product. Vertical bars or carriage return characters serve as parameter information delimiters.

Scatterometer Processing Control (character): additional scatterometer input and processing control parameters used to generate the product. Vertical bars or carriage return characters serve as parameter information delimiters.

Delta TND H coefficient (4-byte float, array size **Number of Beams**): calibration coefficients applied to the Radiometer Ta H polarization for this orbit, computed from the exponential fits. The calculation and application of these coefficients is described in "Instrument calibration (post-launch): Radiometer calibration methodology", J. Piepmeier et al.

Delta TND V coefficient (4-byte float, array size **Number of Beams**): calibration coefficient applied to the Radiometer Ta V polarization for this orbit, computed from the exponential fits (see above).

Radiometer Offset Correction (4-byte float, array size **2*Number of Beams**): offset corrections applied to the radiometer Ta values. These are the estimated residual instrumental errors in the antenna temperatures after the "**Delta TND X coefficient"** gain corrections are applied. The calculation and application of these coefficients is described in "Instrument calibration (post-launch): Radiometer calibration methodology", J. Piepmeier et al. The order is (1V, 1H, 2V, 2H, 3V, 3H). Set to 0.0 if not used.

Radiometer Flag Limits (character): brief listing of limits used to set the radiometer quality flags specified in section 4.2.

Mean Solar 1415 MHz Flux: The noon-time value of solar flux. This is the average value of the stations of the Air Force Radio Solar Telescope Network (RSTN) reporting at 1.4 GHz (Learmonth, San Vito, Sagmore Hill, Palehua). The data are available at: http://www.swpc.noaa.gov/ftpdir/lists/radio/rad.txt. These data are used to compute the contribution of the Sun (direct, reflected and glint) and associated flags.

3.3 Data Time

Start Time (character): start UTC of the first block of the orbit; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

End Time (character): start UTC of the last block of the orbit; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

Node Crossing Time (character): UTC of ascending node crossing; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

Start Year (4-byte integer): UTC year of first block of the orbit.

Start Day (4-byte integer): UTC day-of-year of first block of the orbit.

Start Millisec (4-byte integer): UTC milliseconds-of-day of the first block of the orbit.

End Year (4-byte integer): UTC year of last block of the orbit.

End Day (4-byte integer): UTC day-of-year of last block of the orbit.

End Millisec (4-byte integer): UTC milliseconds-of-day of the last block of the orbit.

3.4 Data Characteristics

Number of Blocks (4-byte integer): number of Aquarius science blocks in the orbit at 1.44-second intervals.

Number of Beams (4-byte integer): 3; number of antenna beams; order is inner, middle, outer.

Radiometer Polarizations (4-byte integer): 4; number of polarizations in raw radiometer data; order is V, +45, -45, H.

Radiometer Subcycles (4-byte integer): 12; the number of 120 msec subcycles in a 1.44 second science block.

Radiometer Signals per Subcycle (4-byte integer): 5, number of radiometer antenna signal measurements in a 120 msec subcycle; first 2 are 20 msec, last 3 are 10 msec.

Scatterometer Polarizations (4-byte integer): 2; number of scatterometer receive polarizations; order is V, H; last dimension of the **scat_rfi_flags** array (Section 4.2)

Scatterometer Subcycles (4-byte integer): 8; the number of 180 msec subcycles in a 1.44 second science block.

3.5 File Metrics

Percent Water (4-byte float): percent of data in this product not contaminated by land.

Percent RFI (4-byte float): percent of radiometer data with the RFI flag set, computed as the number of RFI-flagged 10-ms samples divided by the total samples; if SA1 exclusion is enabled, these samples are not counted as either RFI-flagged or total.

Nominal Navigation (character): “TRUE” or “FALSE”; indicates nominal pointing during the orbit; set to FALSE during maneuvers or anomalies.

Anomaly Status String (character): indicates type of anomaly (if any) that occurred in this orbit; *included only for orbits with anomalies*.

3.6 Orbit Coordinates

Latitude Units (character): "degrees North"; units used for all latitude values in this product.

Longitude Units (character): "degrees East"; units used for all longitude values in this product.

Orbit Number (4-byte integer): orbit number from the start of the mission.

Orbit Node Longitude (4-byte float): longitude of scene's orbit ascending node (longitude at equatorial crossing of PM-side node).

Cycle Number (4-byte integer): number of the weekly cycle from the start of the mission. Cycle 1 started with the first orbit on 25 August 2011. Each cycle will contain 103 orbits.

Pass Number (4-byte integer): pass (orbit) number within the weekly cycle (1 to 103).

4.0 Data Objects

The following groups of data objects -- Block Attributes, Aquarius Flags, Aquarius Data, Navigation, and Converted Telemetry -- contain data that are functions of blocks. That is, each data object within these groups has data for each block and is therefore dimensioned by the value of the global attribute, **Number of Blocks**. For objects that are dimensioned by beam and polarization, the order is specified in **3.4 Data Characteristics**.

4.1 Block Attributes

The following data objects belong to the group "Block Attributes". Attributes of the objects are shown in **bold**.

sec (8-byte float, array size **Number of Blocks**): **long_name** = "Block time, seconds of day"; **valid_range** = (0.d0,86399.999999d0); **units** = "seconds"; mid-block times of Aquarius physical parameter values in seconds of day.

secGPS (8-byte float, array size **Number of Blocks**): **long_name** = "Block time, GPS time"; **units** = "seconds"; block times of Aquarius physical parameter values in seconds since the GPS epoch (0 hours UTC on 6 January 1980).

rad_samples (2-byte integer array size **Number of Blocks** x **Number of Beams** x **Radiometer Polarizations**): **long_name** = "Number of radiometer samples per average"; number of radiometer samples used per block, beam and polarization in the radiometer parameter averages in the **Aquarius Data** group (section 4.3). Samples that are flagged for RFI interference (see **rad_rfi_flags** below) are not used in the averages. Note that the 20-msec DPU averages are counted as 2 samples. The maximum is 84 with all samples and 60 with SA1 excluded.

scat_samples (2-byte integer array size **Number of Blocks** x **Number of Beams**): **long_name** = "Number of scatterometer samples per average"; number of scatterometer samples used per block and beam in the scatterometer parameter averages in the **Aquarius Data** group (section 4.3). Samples that are flagged for RFI interference in either polarization (see **scat_rfi_flags** below) are not used in the averages, so this value is not polarization-dependent. This is done to ensure that RFI detected on one polarization does not corrupt the corresponding sample of the other polarization.

solar xray flux (4-byte float, array size **Number of Blocks**): The peak value of X-ray flux during a solar flare. This is used to generate a flag to identify occurrence of a solar flare. It is a surrogate for the associated L-band flux which is not as readily available. This long wavelength (1-8 A^o) from the GOES satellite is used and is available at: http://www.swpc.noaa.gov/ftpdir/lists/xray.

4.2 Aquarius Flags

The following data objects belong to the group "Aquarius Flags". These represent the non-nominal data conditions that are detected for the radiometer and scatterometer measurements for each block and beam. The bit convention is 0-base, with the LSB as bit 0. Attributes of the objects are shown in **bold**. Beam and polarization order is specified in **3.4 Data Characteristics**.

rad_rfi_flags (byte, array size **Number of Blocks** x **Number of Beams** x **Radiometer Polarizations** x **Radiometer Subcycles**): **long_name** = "Radiometer RFI flags"; Radio frequency interference flags for each radiometer measurement in the block. Bit 2 represents the CND RFI flag. Bits 3 - 7 represent the individual radiometer short accumulations (SA1 - SA5) during each subcycle in a block. Each bit is set to 1 if RFI was detected for that measurement. The MSB and LSB are zero fill. If SA1 is excluded, bit 3 is also zero fill.

scat_rfi_flags (byte, array size **Number of Blocks** x **Number of Beams** x **Scatterometer Polarizations**): **long_name =** "Scatterometer RFI flags"; Radio frequency interference flags for each scatterometer measurement in the block, as identified by either the RFI algorithm on board the Aquarius instrument or the ground-processing RFI detection algorithm. The 8 bits of each entry represent the RFI flags for the individual scatterometer subcycle sequences in each block. There is one bit per sequence per receive polarization, in the sequence order (LSB) sequence 1, sequence 2, …, sequence 8 (MSB), where sequence 1 comes first in time and sequence 8 comes last in the block. The RX polarization order is V-pol, H-pol.

radiometer_flags (4-byte integer, array size **Number of Blocks** x **Number of Beams** x **Max Radiometer Flags**): **long_name** = "Radiometer data quality flags"; each bit represents a data quality condition that was detected for that beam and block. For each flag condition, up to **Max Radiometer Flags** (last array dimension) individual flags are set per beam. Table 1 presents the condition associated with each flag, including the thresholds used; the meaning of the last dimension; the use as a flag or mask at Level-2, and the associated radiometer science data fields. Moderate and severe flags are mutually exclusive (e.g., the moderate flag is 0 if the severe flag is set). Any unused array elements are set to 0. This array has attributes that provide the names of the algorithms used in determining the setting of the flags. The algorithms associated with these names are described in "Flag Documentation", D. M. Le Vine (17 July 2012 draft).

Table 1. Conditions indicated for the pixel associated with the setting of individual bits in **radiometer_flags**, along with the flag dimension and related radiometer data fields

Bit Set = 1	Condition Indicated	Last Flag Dimension	Flag/ Mask	Radiometer Fields
0 (LSB)	RFI moderate contamination 7 <= samples < 15	Polarization (V, P, M, H)	F	rad_samples
1	RFI severe contamination samples < 7	V, P, M, H	F	rad_samples
2	Rain in main beam[1]	V moderate V severe H moderate H severe	F	N/A
3	Land contamination moderate: 0.005<land	moderate severe	F	rad_land_frac

	frac<0.02 severe: land frac>0.02			
4	Sea ice contamination moderate: 0.005<ice frac<0.02 severe: ice frac>0.02	moderate severe	F	rad_ice_frac
5	Wind/foam contamination moderate: 7<wind speed<15 severe: wind speed>15	moderate severe	F	anc_wind_speed
6	Unusual brightness temperature moderate: 1.0<abs(Tf-Ta_exp)<3.0 severe: abs(Tf-Ta_exp)>3.0	V moderate V severe H moderate H severe	F	rad_TfV - rad_exp_TaV rad_TfH - rad_exp_TaH
7	Direct solar flux contamination moderate: 0.02<solar direct<0.05 severe: solar direct>0.05	V moderate V severe H moderate H severe	F	rad_solar_Ta_dir_V rad_solar_Ta_dir_H
8	Reflected solar flux contamination moderate: 0.02<solar reflect<0.05 severe: solar reflect >0.05	V moderate V severe H moderate H severe	F	rad_solar_Ta_ref_V rad_solar_Ta_ref_H
9	Sun glint moderate: 0.02<solar glint<0.05 severe: solar glint>0.05	V moderate V severe H moderate H severe	F	rad_solar_Ta_bak_V rad_solar_Ta_bak_H
10	Moon contamination moderate: 0.02<moon reflected<0.05 severe: moon reflected >0.05	V moderate V severe H moderate H severe	F	rad_moon_Ta_ref_V rad_moon_Ta_ref_H
11	Galactic contamination moderate: 0.02<galactic<0.05 severe: galactic>0.05	V moderate V severe H moderate H severe	F	rad_galact_Ta_ref_V rad_galact_Ta_ref_H
12	Non-nominal navigation abs(roll)>1.0 or acs_mode ne 5 abs(pitch)>5.0 or acs_mode ne 5 abs(yaw)>4.0 or acs_mode ne 5 clat, clon = -999	roll, pitch, yaw OOB	F M	att_ang acs_mode beam_clat beam_clon
13	SA overflow Overflow bit set in NRT telemetry	overflow	M	radiom_nrt_tlm (L1A)

14	Full roughness correction not performed (1 = partial correction)	Partial correction	F	N/A
15	Solar flare contamination	moderate severe	F	
16 - 31 (MSB)	Spares			

([1]) Not currently implemented

scatterometer_flags (4-byte integer, array size **Number of Blocks** x **Number of Beams**): **long_name** = "Scatterometer data quality flags"; each bit represents a data quality condition that was detected for that beam and block. The algorithms associated with these flags, and the use of the corresponding bits as masks or as flags, are fully described in the Scatterometer Science Processing Software User Manual, AQ-485-0541, JPL D-51444.

Table 2. Conditions indicated for the pixel associated with the setting of individual bits in **scatterometer_flags**.

Bit Set = 1	**Condition Indicated**
(LSB) 0 –	Spares
11	Overall quality (1 = poor)
12	Negative power computed for TOI (antenna) HH
13	Negative power computed for TOI (antenna) VH
14	Negative power computed for TOI (antenna) VV
15	Negative power computed for TOI (antenna) HV
16	Unsuccessful Faraday rotation removal HH
17	Unsuccessful Faraday rotation removal VH
18	Unsuccessful Faraday rotation removal VV
19	Unsuccessful Faraday rotation removal HV
20	Non-nominal attitude (e.g., roll, pitch or yaw out of
21	Scatterometer beams off Earth
22	Negative power computed for TOA HH sigma-0
23	Negative power computed for TOA VH sigma-0
24	Negative power computed for TOA VV sigma-0
25	Negative power computed for TOA HV sigma-0
26	Rain in main beam (moderate)[1]

27	Rain in main beam (severe)[1]
28	RFI corruption of H-pol signal (moderate)
29	RFI corruption of H-pol signal (severe)
30	RFI corruption of V-pol signal (moderate)
31 (MSB)	RFI corruption of V-pol signal (severe)

([1]) Not currently implemented

4.3 Aquarius Data

The Aquarius computed physical parameters in the Level-2 product are stored in data objects belong to the group “Aquarius Data". The complete list of available parameters is given in Sections 4.3.1 (Radiometer), 4.3.2 (Scatterometer), and 4.3.3 (Ancillary data. Each data object has a data type of 4-byte float and dimensions **Number of Blocks** x **Number of Beams**. All objects have standard attributes **long_name**, **valid_min**, **valid_max**, and **_FillValue**.

4.3.1 Radiometer Data

This section describes the Aquarius radiometer science data parameters, including references to the appropriate sections of the radiometer ATBD. Where the same parameter is provided at multiple polarizations, a single description is provided with the polarizations listed (e.g., {V, H}). Each data object has dimensions **Number of Blocks** x **Number of Beams**.

rad_TaX0, X = {V, H, 3}: Radiometer antenna temperature at polarization X. This is the radiometer output (TOI), calibrated (counts to TA) and averaged to 1.44 sec blocks with no other processing.

rad_TaX, X = {V, H, 3}: Radiometer antenna temperature at polarization X corrected for instrumental errors. This is the radiometer output (TOI), calibrated (counts to TA) and averaged to 1.44 sec blocks (same as **rad_TaX0**), with a gain adjustment (specified by **Delta TND X coefficient**) and offset correction (**Radiometer Offset Correction**) applied (see description of these corrections in Section 3.2).

rad_TfX0, X = {V, H, 3}: Radiometer antenna temperature at polarization X after RFI removal. This is the radiometer output (TOI), calibrated (counts to TA) and averaged to 1.44 sec blocks (same as **rad_TaX0**) after RFI has been removed.

rad_TfX, X = {V, H, 3}: Radiometer antenna temperature at polarization X corrected for instrumental errors and RFI removal. This is the radiometer output (TOI), calibrated and averaged to 1.44 sec blocks (same as **rad_TaX**) but with RFI removed

rad_toi_X, X = {V, H, 3}: Brightness temperature from the surface at the radiometer (i.e. top of the ionosphere,TOI) at polarization X. This is obtained from the radiometer antenna temperature after RFI removal, **rad_TfX**, by removing all non-surface sources (except the atmosphere) and then applying the antenna pattern correction, APC. (ATBD, Section 3.3, Equation 46.)

rad_toa_X_nolc, X = {V, H}: Brightness temperature at the top of the atmosphere (TOA) at polarization X. This is obtained from the radiometer brightness temperature, **rad_toi_X**, by applying a correction for Faraday rotation. The Faraday rotation angle is obtained from **rad_toi_X**, using the ratio of the third and second Stokes parameters. (ATBD, Section 3.4, Equations 47-48).

rad_toa_X, X = {V, H}: Brightness temperature at the top of the atmosphere (TOA) at polarization X with a correction for land contamination. This is obtained from the radiometer brightness temperature, **rad_toa_X_nolc**, by applying an additional correction for contamination due to land appearing in the antenna sidelobes. This is not a correction for land in the main beam. (ATBD, Section 3.8, Equation 55)

rad_far_TaH: Faraday rotation angle determined from the ratio of the third and second Stokes parameters using data in **rad_TfX.** This is the angle used in converting from **rad_toi_X** to rad**_toa_X_nolc** (ATBD, Section 3.4, Equations 47-48).

rad_galact_Ta_dir_X, X = {V, H, 3}: Celestial background radiation at L-band impinging directly on the radiometer antenna. In nominal operation it enters via the antenna sidelobes (ATBD Section 2.2.1).

rad_galact_Ta_ref_X, X = {V, H, 3}: Celestial background radiation at L-band after reflection from the Earth surface. In nominal operation (i.e. pointing toward the surface) it enters primarily via the antenna mainbeam. A constant value of 3.0 K is removed and treated separately (ATBD Section 2.2.1).

rad_solar_Ta_dir_X, X = {V, H, 3}: Direct radiation from the Sun. Radiation from the Sun, arriving via line-of-sight from the Sun. This enters via the radiometer antenna sidelobes. The radiation is proportional to the mean solar flux (no flares). (ATBD Section 2.2.3)

rad_solar_Ta_ref_X, X = {V, H, 3}: Reflected radiation from the Sun. The radiation arrives after reflection from the Earth surface and enters through the antenna side lobes. The radiation is proportional to the mean solar flux (no flares). (ATBD Section 2.2.4)

rad_solar_Ta_bak_X, X = {V, H, 3}: Sun glint. Radiation from the Sun which is scattered from the rough ocean surface toward the radiometer. This is only significant when the footprint of the main antenna beam is illuminated by the Sun. (ATBD Section 2.2.5)

rad_moon_Ta_ref_X, X = {V, H, 3}: Radiation from the Moon at polarization X after reflection from the Earth. This is important several times each month when the reflection occurs close to the footprint of the antenna main beam (ATBD Section 2.2.6).

rad_TbX, X = {V, H}: Brightness temperature at the surface prior to making a correction for roughness. This is obtained from **rad_toa_X** after correction for attenuation and emission from the atmosphere (ATBD Section 3.5).

rad_TbX_nolc, X = {V, H}: Brightness temperature at the surface prior to making a correction for roughness but without the correction for land in the antenna sidelobes. This is obtained from **rad_toa_X_nolc** after correction for attenuation and emission from the atmosphere (ATBD Section 3.5).

rad_TbX_rc, X = {V, H}: Brightness temperature at the surface after making a correction for roughness. This is obtained from **rad_TbX** after correction for roughness (ATBD Section 3.6; Addendum, Section III).

rad_TbX_rc_nolc, X = {V, H}: Brightness temperature at the surface after making a roughness correction but without making a correction for land in the sidelobes. This is obtained from **rad_TbX_nolc** after correction for roughness (ATBD Section 3.6; Addendum Section III).

rad_Tb_consistency: Magnitude of the difference between the measured brightness temperature at the surface after all corrections (**rad_TBX_rc**) and the predicted values obtained using the derived SSS (not HYCOM) and a flat surface. The difference is squared, summed over both polarizations and the square root taken. However, the difference at V-pol is zero because **rad_TbV_rc** is used to derive the SSS. Hence, this is the magnitude of the difference at H-pol.

rad_Tb_consistency_nolc: Same as **rad_Tb_consistency** but using the measured values before land correction (i.e. using **rad_TbX_nolc_rc**)**.**

SSS: Retrieved sea surface salinity. Uses only vertical polarization. Obtained from **rad_TbV_rc** (ATBD Section 3.6; Addendum Section IV).

SSS_error: Estimated uncertainty in **SSS**; not currently implemented.

SSS_nolc: Retrieved sea surface salinity with no land sidelobe correction. Uses only vertical polarization. Obtained from **rad_TbV_nolc_rc** (ATBD Section 3.6; Addendum Section IV).

SSS_error_nolc: Estimated uncertainty in **SSS_nolc**; not currently implemented.

rad_exp_TaX, X = {V, H, 3}: Model derived radiometer antenna temperature. The antenna temperature is obtained using the salinity field from the HYCOM model and working the retrieval algorithm in reverse (ATBD Section 3.7).

rad_exp_TbX, X = {V, H}: Predicted brightness at the surface using the HYCOM salinity field. The brightness temperature (ATBD, Equation 43-44) is computed for a smooth surface to which the roughness correction (ATBD, Addendum, Section III) is added.

rad_exp_TbX0, X = {V, H}: Brightness temperature of an ideal surface (i.e. flat, with no waves) and with the salinity of the HYCOM reference ocean and Reynolds SST, but modified as described in Equations 43-44 of the ATBD.

4.3.2 Scatterometer Data

This section describes the Aquarius radiometer science data parameters. Where the same parameter is provided at multiple polarizations, a single description is provided with the polarizations listed (e.g., {V, H}). Each data object has dimensions **Number of Blocks** x **Number of Beams**.

scat_X_ant, X = {VV, HH, HV VH}: Estimated normalized radar cross-section (NRCS, or sigma-0) at the antenna (i.e., TOI, top of ionosphere) for each polarization.

scat_X_toa, X = {VV, HH, HV VH}: Estimated normalized radar cross-section (NRCS, or sigma-0) at the top of the atmosphere (TOA), after Faraday rotation and cross-pol leakage corrections, for each polarization.

scat_tot_toa: Estimated normalized radar cross-section (NRCS, or sigma-0) for the total power received by the radar for each beam (the sum of the power in all four channels, which is independent of Faraday rotation).

scat_wind_speed: Estimated wind speed at the ocean surface.

wind_uncertainty (4-byte real, array size **Number of Blocks** x **Number of Beams): long_name =** "Estimated wind speed error"; **units** = m/s; Estimated uncertainty in wind speed at the ocean surface. This is currently a lower bound for the error, derived from the Kpc variance propagated through wind retrieval.

scat_esurf_X, X = {V, H}: Excess surface emissivity due to wind for V and H polarizations derived from scatterometer data and the radiometer model function.

scat_esurf_X_uncertainty, X = {V, H}: Estimated uncertainty in excess surface emissivity for V and H pol. This is currently a lower bound for the error, derived from the Kpc variance propagated through wind retrieval.

SKpc_X_ant , X = {VV, HH, HV VH}: Statistical uncertainty for the antenna sigma-0 (Kpc = sqrt(var(sig-0))/sig-0)

Kpc_X_toa , X = {VV, HH, HV VH}: Statistical uncertainty for the top-of-atmosphere sigma-0 (Kpc = sqrt(var(sig-0))/sig-0). Algorithm still TBD; current KPC_TOA output is preliminary.

Kpc_total: Statistical uncertainty for the total power sigma-0.

scat_X_exp, X = { VV, HH, HV VH }: Estimated normalized radar cross-section (NRCS, or sigma-0) at the surface for each polarization, predicted using a geophysical model based on the wind data set over ocean only. Over land, this value defaults to -999.

4.3.3 Ancillary Data

The ancillary data parameters used for the Aquarius science data processing are described in this section. All parameters are interpolated in space and time to the Aquarius beam footprints unless otherwise specified. Each data object has dimensions **Number of Blocks** x **Number of Beams**.

anc_wind_speed: The wind speed from NCEP GFS GDAS at 10 m. Data is available from: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/. In the L2 algorithm this NCEP GDAS wind speed is multiplied by a factor of 1.03 in order to make it consistent with observations from buoys and microwave satellites (SSM/I, WindSat).

anc_wind_dir: The wind direction over the ocean is obtained from the NCEP GFS GDAS 10 meter level. The direction conforms to the meteorological convention (i.e. the wind direction is the direction from which the wind is blowing). In the current algorithm for the roughness correction, the direction dependence is determined using this value (expressed as azimuthal angle relative to the look direction, **celphi**). Both radiometer and scatterometer observations are corrected

for wind direction. (ATBD, Addendum I). Data is available from: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/.

anc_cwat: The total columnar liquid water above the viewed location. In the processing, it is used to calculate the integral along the slant path of the radiometer boresight. Approximately, this is the value obtained by dividing by cosine (**celtht**, see Table 3). The actual calculation is done slightly differently (see ATDB). The data are obtained from the NCEP GFS GDAS at: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/.

a**nc_swe:** The snow water equivalent from NCEP GFS GDAS. Data is obtained from: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/.

anc_surface_temp: The surface temperature over the ocean is the NOAA OISST (Reynolds) product. Over land, the NCEP GFS GDAS product for the surface layer is used. Data is available from: ftp.emc.ncep.noaa/gov/cmb/sst/oisst_v2/YEARLY_FILES

anc_surface_pressure: Atmospheric pressure is obtained from the NCEP GFS GDAS. The value at the surface at radiometer boresight is listed in this field (the vertical profile is used in the algorithm; ATBD, Section 2.3.2). Data is obtained from: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/.

anc_subsurf_temp: The subsurface temperature over the land is the NCEP GFS GDAS product for the layer (0-10 cm) because emission from this layer is most closely correlated with soil moisture. This field is not valid over the ocean. Data is obtained from: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/.

anc_SSS: The reference sea surface salinity used for computing **rad_exp_TbX** . It is obtained from the hybrid coordinate ocean model (HYCOM: http://hycom.org) with data assimilation, operated in support of US Navy operations and provided by the Florida State University Center for Ocean-Atmosphere Prediction Studies (FSU/COAPS).

anc_trans: A measure of attenuation through the atmosphere. It is the parameter, $\tau(0,S)$, defined in equation 28-29 in the section 2.3.1 of the Level-2 ATBD. When $\tau(0,S) = 0$ the path is completely opaque.

anc_Tb_up: A measure of the upwelling radiation from the atmosphere at L-band. It is expressed as the effective brightness temperature at the top of the atmosphere and defined by Equation 30 in Section 2.3.1 of the Level-2 ATBD.

anc_Tb_dw: A measure of the downwelling radiation from the atmosphere at L-band. It is expressed as the effective brightness temperature at the bottom of the atmosphere and defined by Equation 31 in Section 2.3.1 of the Level-2 ATBD.

anc_sm: The soil moisture content when over land. This is obtained from the NCEP GFS GDAS operational data product at 1 degree resolution: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/.

rad_land_frac: The gain weighted land fraction: Integration over the radiometer footprint with 1 = land and 0 = non-land (water and sea ice) weighted by the antenna pattern. Computation is made using the GSFC ODPS (SeaWiFS) 1 km resolution land mask. “Land” includes ice/snow covered land.

rad_ice_frac: The gain weighted fraction of sea ice in the radiometer footprint. The Integration is over the radiometer footprint with 0 = water and 0 = land and 1 =

sea ice weighted by the antenna pattern. Computation is made using the NCEP GFS GDAS ice product: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/.

scat_land_frac: The gain weighted fraction of land in the scatterometer footprint. The computation is made using the 2-way beam pattern and GSFC ODPS 1 km land mask. Land fractions should be less than 0.005, and preferably less than 0.001. See the "Scatterometer Science Processing Software (L1A_to_L2) User Manual" for additional information.

scat_ice_frac: The gain weighted fraction of sea ice in the scatterometer footprint. The computation is made using the 2-way beam pattern and the NCEP sea-ice map: ftp.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/ . The values range from 0.0 (no sea ice) to 1.0 (totally ice). Sea ice errors should be less than 0.02. See the "Scatterometer Science Processing Software (L1A_to_L2) User Manual" for additional information.

4.4 Navigation

The group "Navigation" includes the spacecraft orbit and attitude information, celestial object locations and the geolocation fields. For the last, there are separate fields for the radiometer, the scattermeter, and the MWR. The spacecraft and celestial object fields are described below, and the geolocation fields are given in Table 3. All of the fields in Table 3 have a data type of 4-byte float and dimensions **Number of Blocks** x **Number of Beams**; the fields cellatfoot, cellonfoot, scat_latfoot and scat_lonfoot have an additional dimension of 4 corresponding to the four beam ellipse points. All geolocation fields are computed at the mid-block times represented by the data field **sec** in the **Block Attributes** group.

orb_pos (8-byte float, array size **Number of Blocks** x 3): **long_name** = "Orbital position vector"; **valid_range** = (-7100000.,7100000.); **units** = "meters"; orbit position vector at mid-block times; used to determine spacecraft position for geolocation.

orb_vel (8-byte float, array size **Number of Blocks** x 3): **long_name** = "Orbital velocity vector"; **valid_range** = (-7600.,7600.); **units** = "meters per second"; orbit velocity vector at mid-block times; used to determine spacecraft position for geolocation.

sclon (8-byte float, array size **Number of Blocks**): **long_name** = "Spacecraft nadir point longitude"; **valid_range** = (-180., 180.); **units =** “degrees"; longitude of the spacecraft orbit nadir point.

sclat (8-byte float, array size **Number of Blocks**): **long_name** = " Spacecraft nadir point latitude"; **valid_range** = (-90., 90.); **units =** “degrees"; latitude of the spacecraft orbit nadir point.

scalt (8-byte float, array size **Number of Blocks**): **long_name** = "Spacecraft altitude"; **valid_range** = (650,000., 690,000.); **units =** “meters"; spacecraft orbit altitude.

zang (8-byte float, array size **Number of Blocks**): **long_name** = "Intra-Orbit Angle"; **valid_range** = (0., 360.); **units =** “degrees"; angle within orbit from South pole passage at mid-block times.

att_ang (8-byte float, array size **Number of Blocks** x 3): **long_name =** “Spacecraft roll, pitch, yaw"; **valid_range** = (-180.,180.); spacecraft attitude Euler angles at mid-block times; relates spacecraft orientation to orbit reference frame.

acs_mode (1-byte integer, array size **Number of Blocks**): **long_name =** “ACS control mode"; spacecraft attitude control system (ACS) mode for each block (5 = science, 6 = propulsion, 3 = safehold, 12 = survival).

sund (8-byte float, array size **Number of Blocks** x 3): **long_name** = "Earth-to-Sun unit vector (eci)"; **valid_range** = (-1,1); **units** = "unitless"; direct Sun vector in ECI coordinates at mid-block times.

sunr (8-byte float, array size **Number of Blocks** x 3): **long_name** = "Sun reflection unit vector (eci)"; **valid_range** = (-1,1); **units** = "unitless"; reflected Sun vector in ECI coordinates at mid-block time.

moond (8-byte float, array size **Number of Blocks** x 3): **long_name** = "Earth-to-Moon unit vector (eci)"; **valid_range** = (-1,1); **units** = "unitless"; Moon vector in ECI coordinates at mid-block time.

Table 3. Available Geolocation Parameters for Aquarius Level-2 Products

Name	Long Name	Valid Range	Units
beam_clat	Beam Center Latitude	-90 – 90	Degrees
beam_clon	Beam Center Longitude	-180 – 180	Degrees
cellatfoot	Geodetic Latitudes (3 db)	-90 – 90	Degrees
cellonfoot	Geodetic Longitudes (3db)	-180 – 180	Degrees
celtht	Boresight Earth Incidence Angle	0 – 90	Degrees
celphi	Boresight Earth Azimuth Angle	0 – 360	Degrees
sunglt	Sun Glint Angle	-180 – 180	Degrees
suntht	Sun Vector Earth Incidence Angle	-180 – 180	Degrees
sunphi	Sun Vector Earth Azimuth Angle	0 – 360	Degrees
moonglt	Moon Glint Angle	0 – 180	Degrees
glxlat	Galaxy Declination (J2000)	-90 – 90	Degrees
glxlon	Galaxy Right Ascension (J2000)	0 - 360	Degrees
scat_beam_clat	Scatterometer Beam Center Latitude	-90 – 90	Degrees
scat_beam_clon	Scatterometer Beam Center Longitude	-180 - 180	Degrees
scat_latfoot	Scatterometer Latitude Footprint	-90 – 90	Degrees
scat_lonfoot	Scatterometer Longitude Footprint	-180 - 180	Degrees
scat_polarization_roll	Scatterometer Polarization Roll Angle	-180 - 180	Degrees

4.4 Converted Telemetry

The following data objects belong to the group "Converted Telemetry". Attributes of the objects are shown in **bold**. This group contains Aquarius temperatures in the **rad_caltemps** object, unpacked from raw telemetry and converted to physical units; and the computed radiometer gain and offset values used to calibrate the antenna brightness temperatures, shown in Table 4. The data objects in the table each have dimensions **Number of Blocks** x **Number of Beams**.

rad_caltemps (4-byte float, array size **Number of Blocks** x 85): **long_name** = "Radiometer calibration temperatures"; Aquarius temperatures used to calibrated the instrument brightness temperatures.

Table 4. Radiometer Calibration Gains and Offsets

Name	Long Name
rad_ghh	Radiometer HH gain
rad_gmm	Radiometer MM gain
rad_gpp	Radiometer PP gain
rad_gvv	Radiometer VV gain
rad_oh	Radiometer H offset
rad_om	Radiometer M offset
rad_op	Radiometer P offset
rad_ov	Radiometer V offset

5.0 Change Log

Date	Description	By
3/6/2012	Added fields and metadata to the product format to reflect the ND-based radiometer calibration correction and the scatterometer-based roughness correction; removed SSS_land; added new radiometer flags.	Fred Patt
3/8/2012	Removed unneeded calibration fields from Converted Telemetry group.	Fred Patt
3/20/2012	Added uncorrected Tb back; added DR fit coefficients as metadata	Fred Patt
4/9/2012	Revised radiometer flag structure; changed rad_Tb_error to rad_Tb_consistency.	Fred Patt
7/31/2012	Revised radiometer flags and improve description according to recommendations by D. Le Vine; updated scatterometer fields based on software user's guide update, and field/flag descriptions based on input from A. Freedman.	Fred Patt
8/23/2012	Added new radiometer fields for V1.3.4; corrected and clarified multiple items based on comments from D. Le Vine.	Fred Patt
9/17/2012	Added new radiometer fields for V1.3.5.	Fred Patt
12/13/2012	Added new metadata and ancillary fields for V1.3.7.	Fred Patt
1/30/2013	Revamped the description of the Aquarius science data fields; updated the global and object-level attributes to be CF compliant.	Fred Patt
2/12/2013	Mean solar L-band flux made a global attribute; X-ray flux moved to **Block Attributes**.	Fred Patt